

Solid Oxide Fuel Cell Hybrid System for Distributed Power Generation

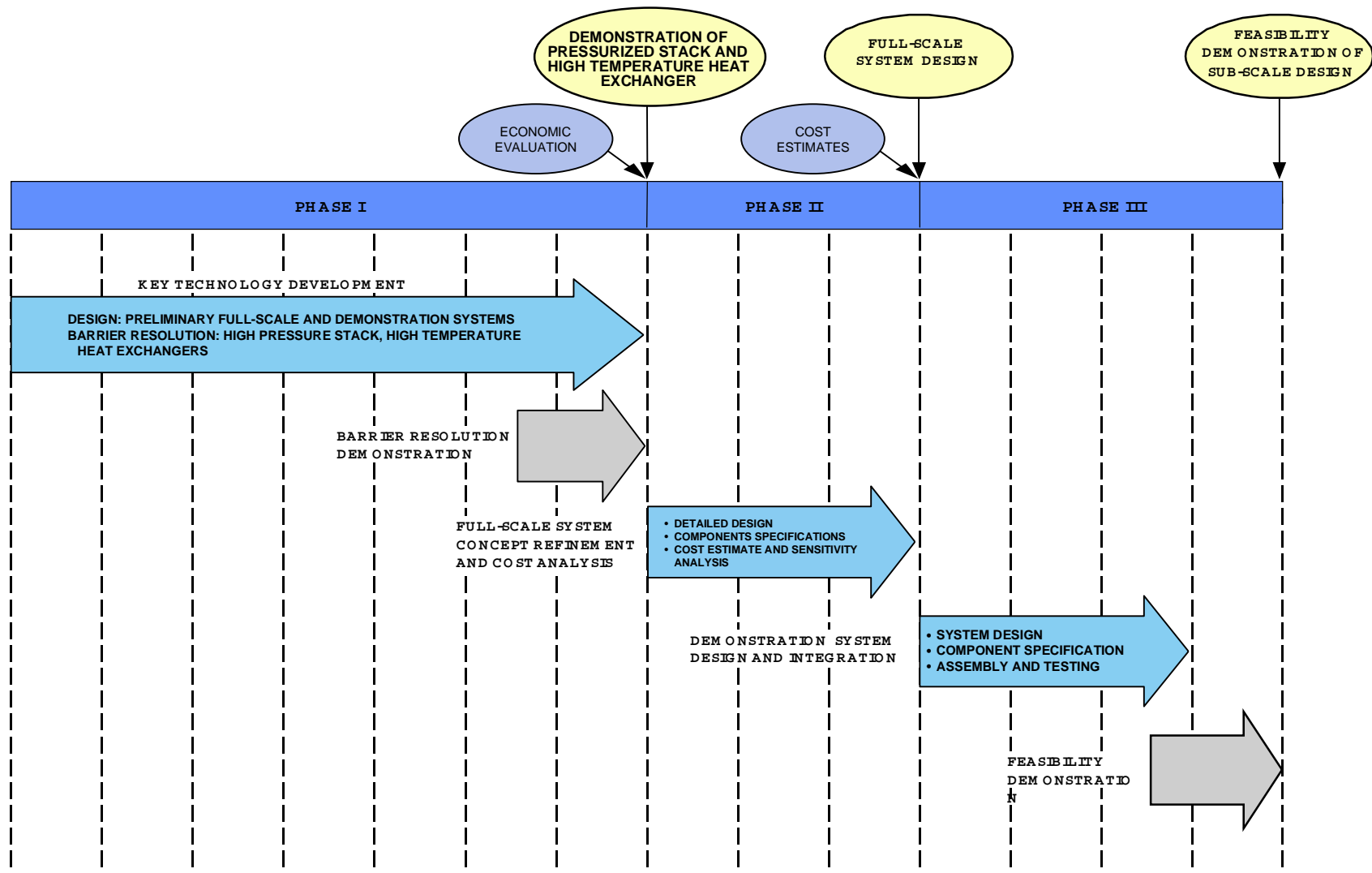
Nguyen Minh

**Galveston, TX
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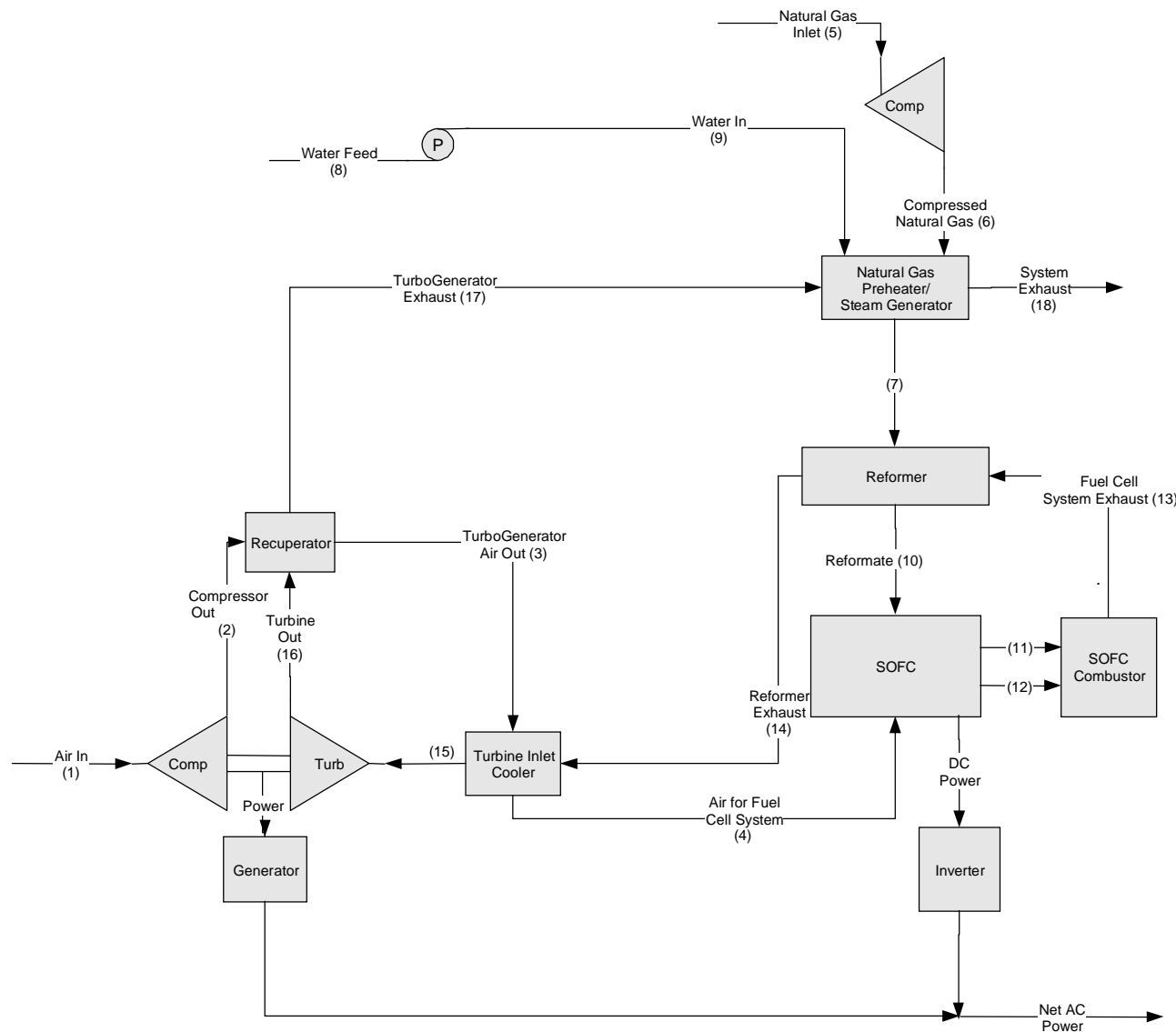
DOE Program Objective

- **Overall objective**
 - Develop and demonstrate the feasibility of a highly efficient hybrid system integrating a planar solid oxide fuel cell (SOFC) and microturbine
- **Approach**
 - Technology base:
 - ◆ Planar SOFC technology
 - ◆ Microturbine technology
 - System approach along with other design methodologies

Program Features

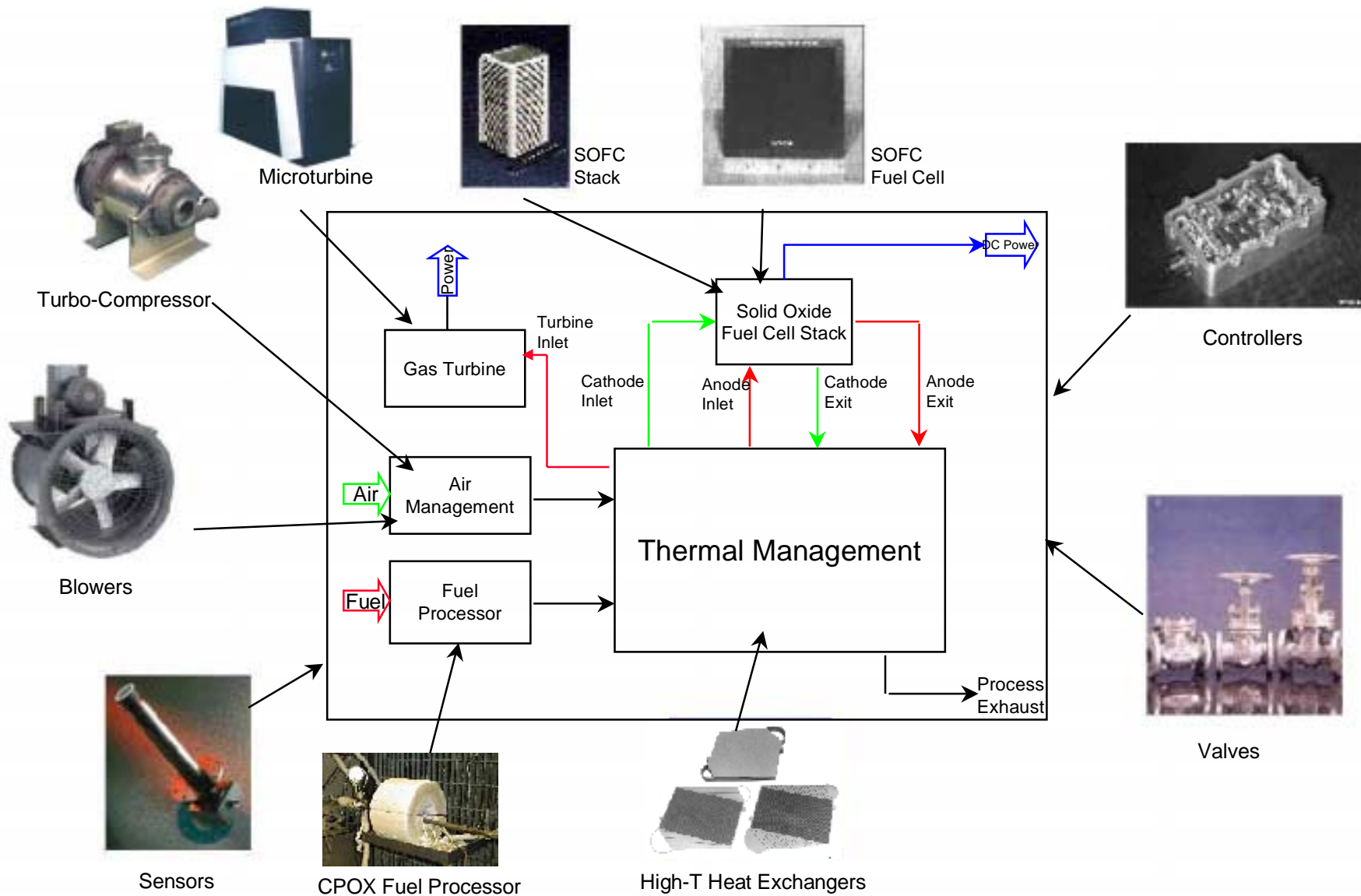


SOFC Hybrid System Concept



Honeywell

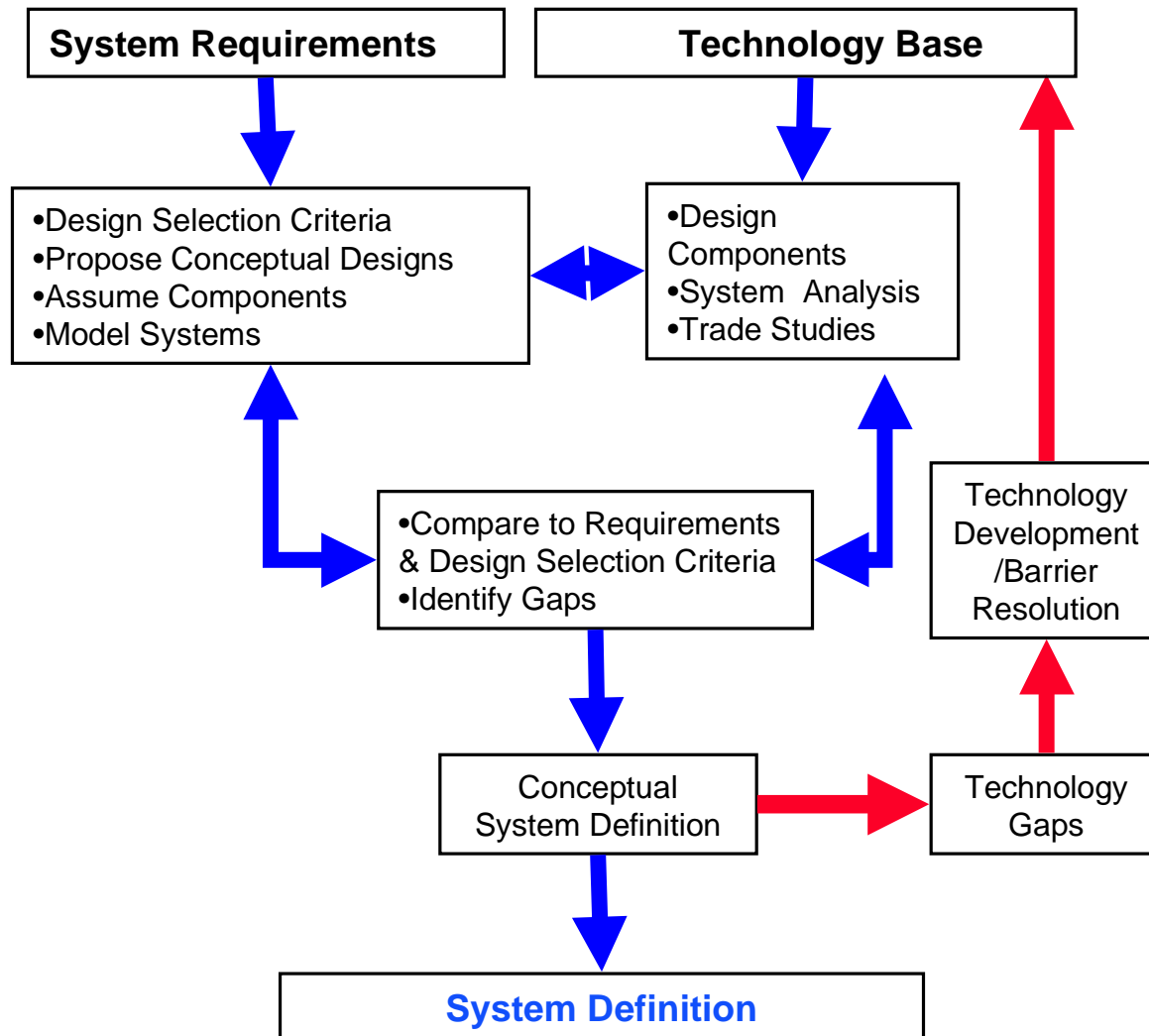
Simplified SOFC System & Components



Key System Features

- **SOFC**
 - High-performance reduced-temperature planar cells
 - Honeywell low-cost tape calendering manufacturing process
- **Microturbine**
 - Commercial systems
- **Other subsystems**
 - Fuel processor
 - Thermal management
 - Flexible control subsystem

System Design Approach



Design Criteria for Conceptual System

- **Efficiency**
- **Cost**
- **High reliability**
- **Small volume (but not at the expense of efficiency)**

Assumptions for DOE System Design

- **Natural gas**
- **Base-load system operation**
- **Pressurized SOFC operation**
- **High fuel utilization ~75% in SOFC with possible internal reforming**
- **Cell voltage ~0.75 V at a reasonable current density**
- **Commercially available microturbine & turbocharger**
- **High-temperature heat transfer equipment will be available**

Performance Estimate for a SOFC-Microturbine Hybrid System

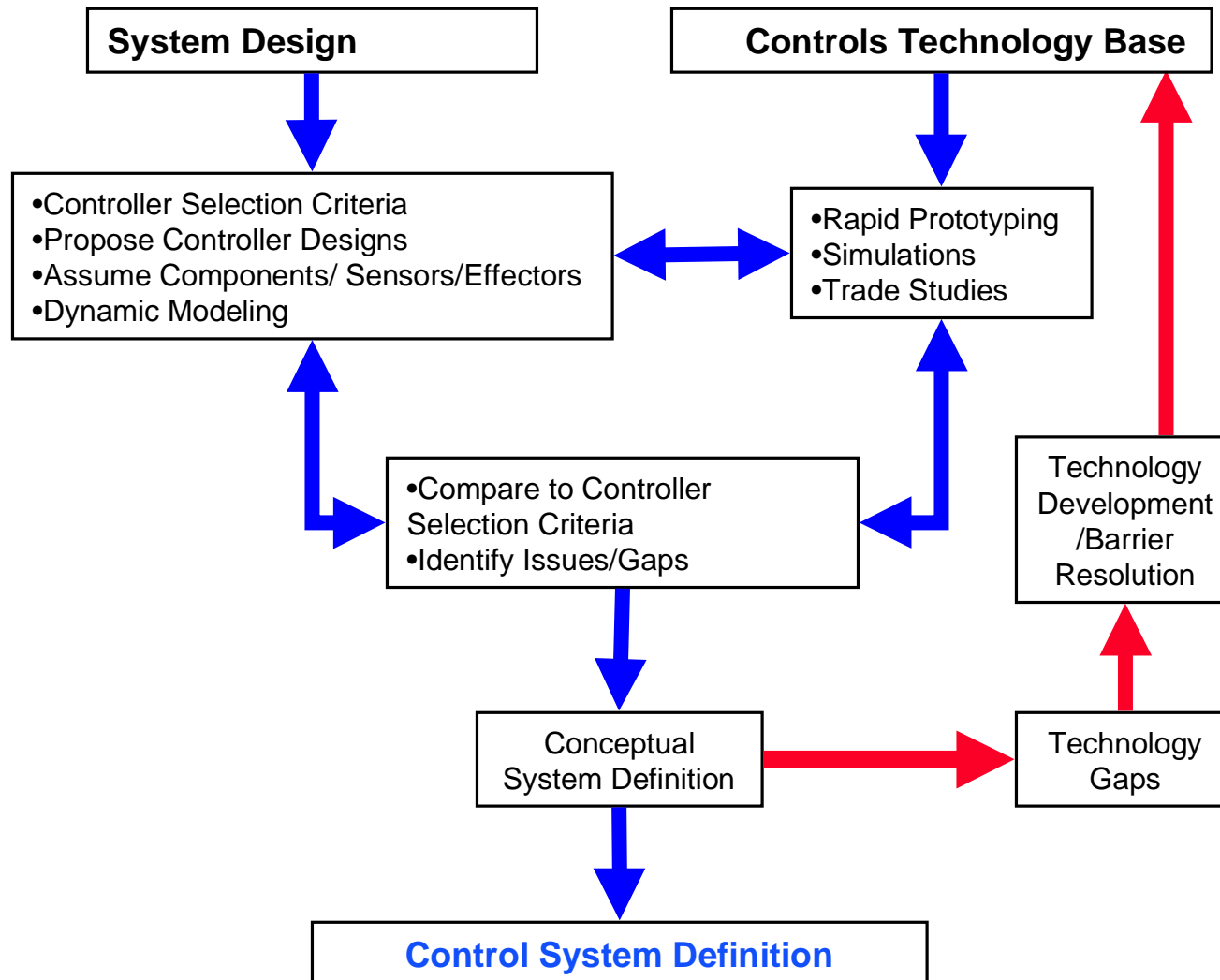
System Net Power **475 kW**

Microturbine Power **97 kW**

SOFC Power **384 kW**

System Efficiency **67%**

Control System Design Approach

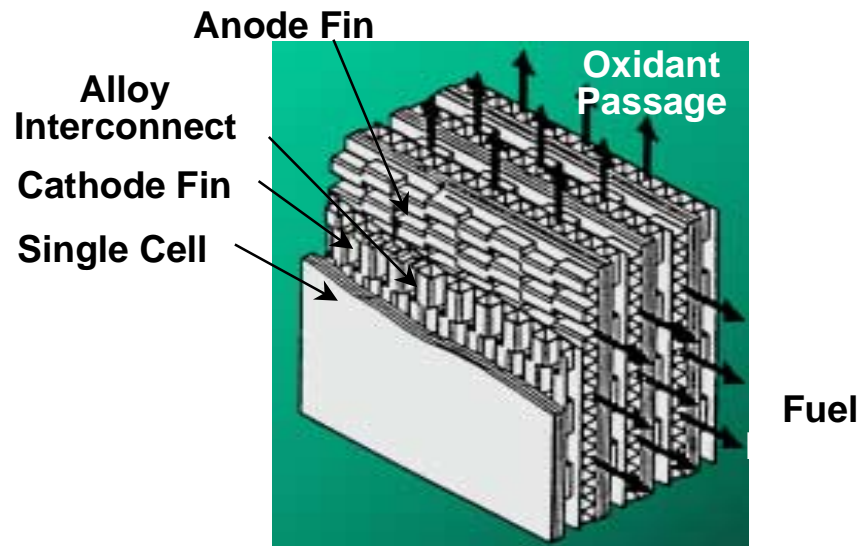


Control System Definition

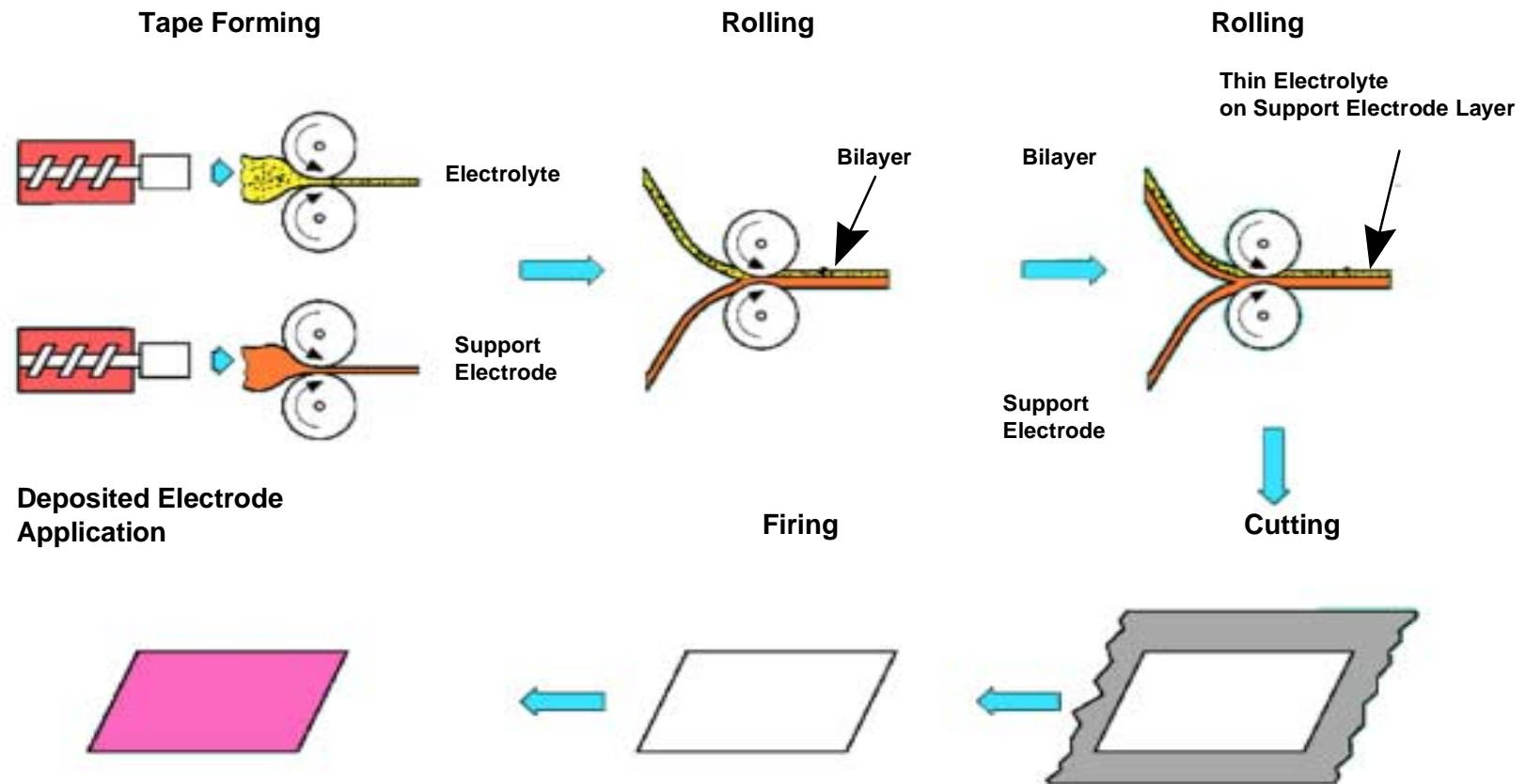
- **Supervisory control**
- **System health monitoring**
- **Sensing and measurement**
- **Valves/Actuators**

SOFC Stack Design Features

- Anode-supported thin-electrolyte cells to permit efficient operation at reduced temperatures
- Lightweight metallic structures to achieve high power densities
- Stack design flexibility including gas manifold and flow configuration

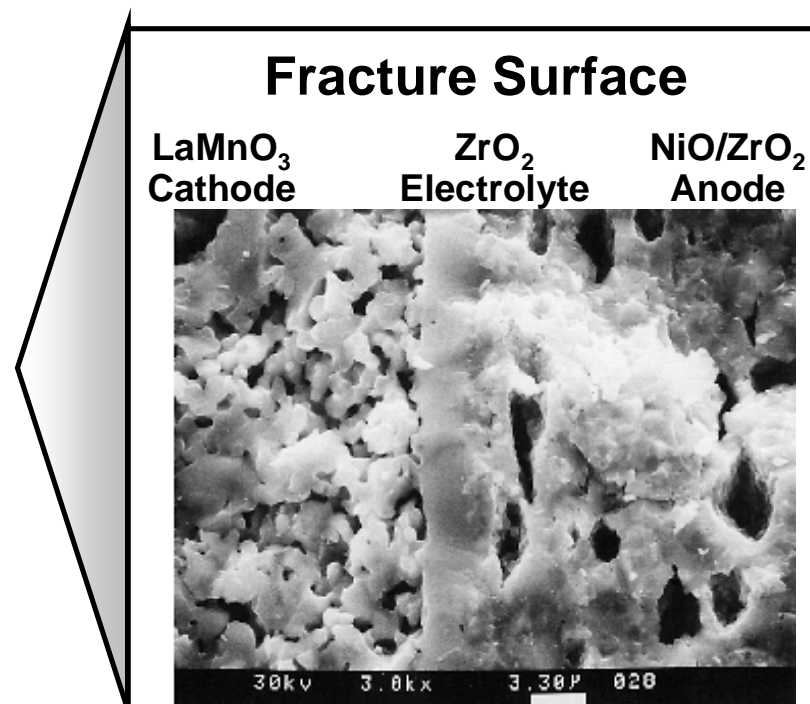


Cell Fabrication

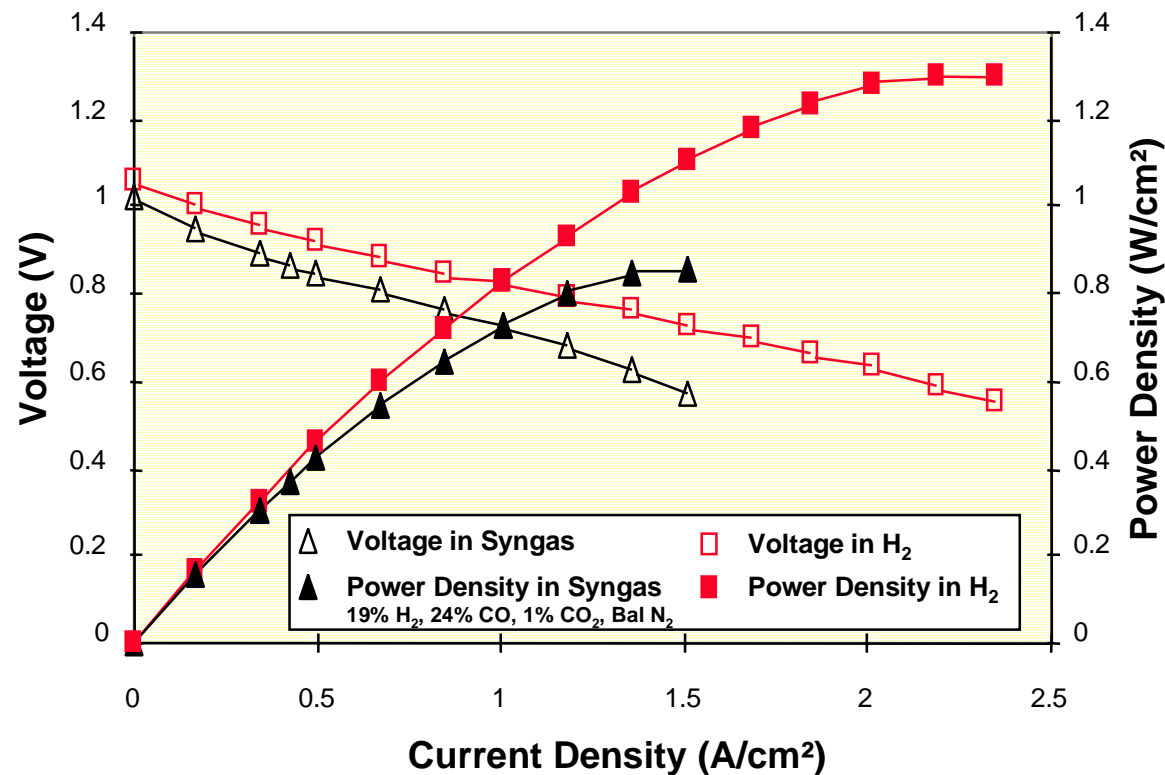


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High-Performance Anode-Supported SOFC



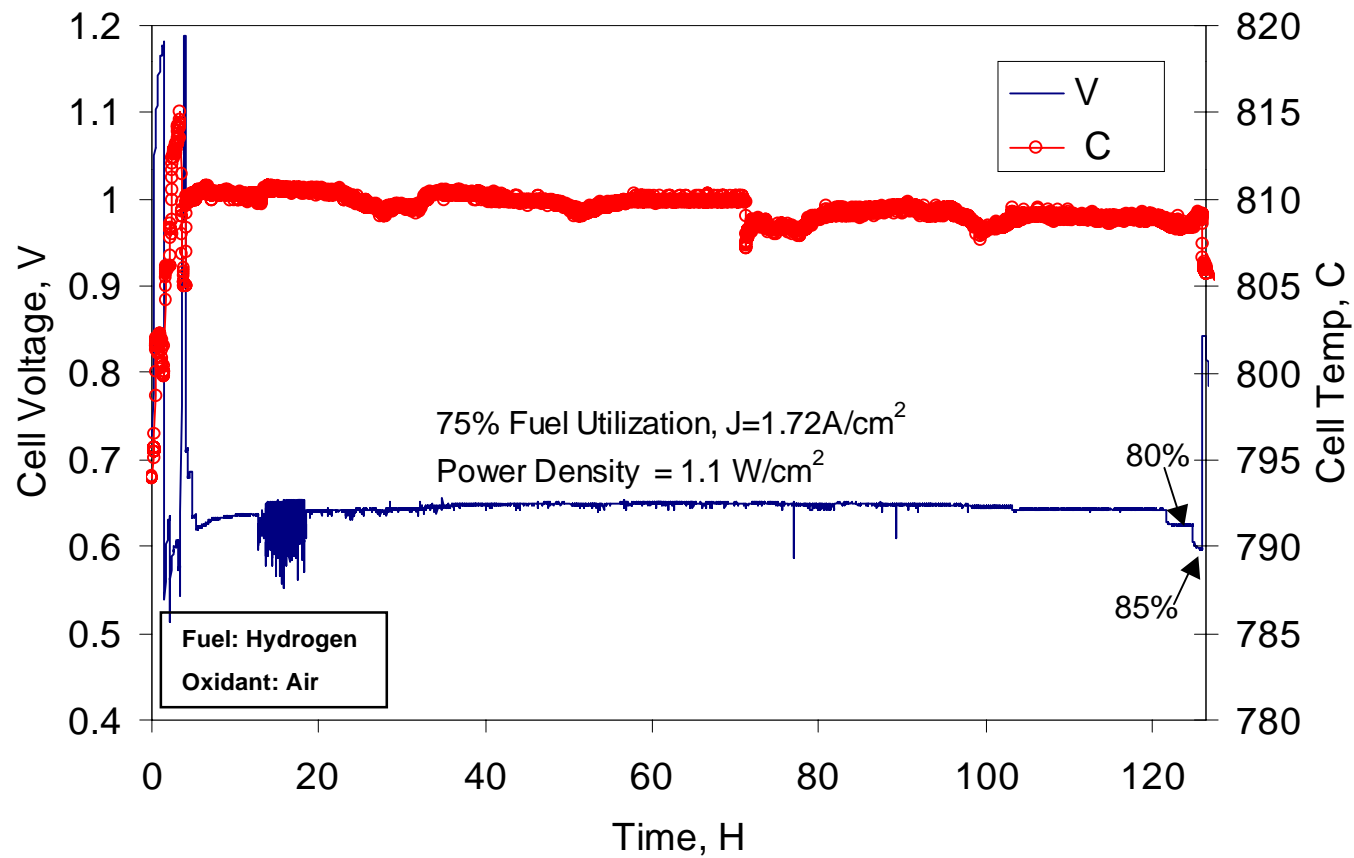
SOFC Cell Performance



- 800°C operation
- Peak power density:
 - 1.3 W/cm² in hydrogen
 - 0.85 W/cm² in syngas

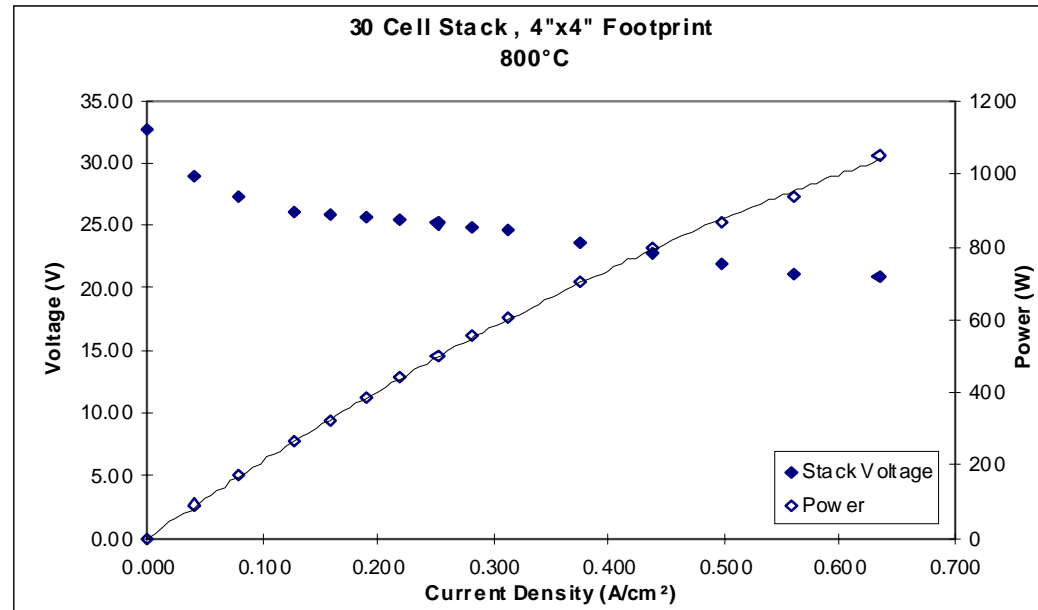
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Cell Fuel Utilization



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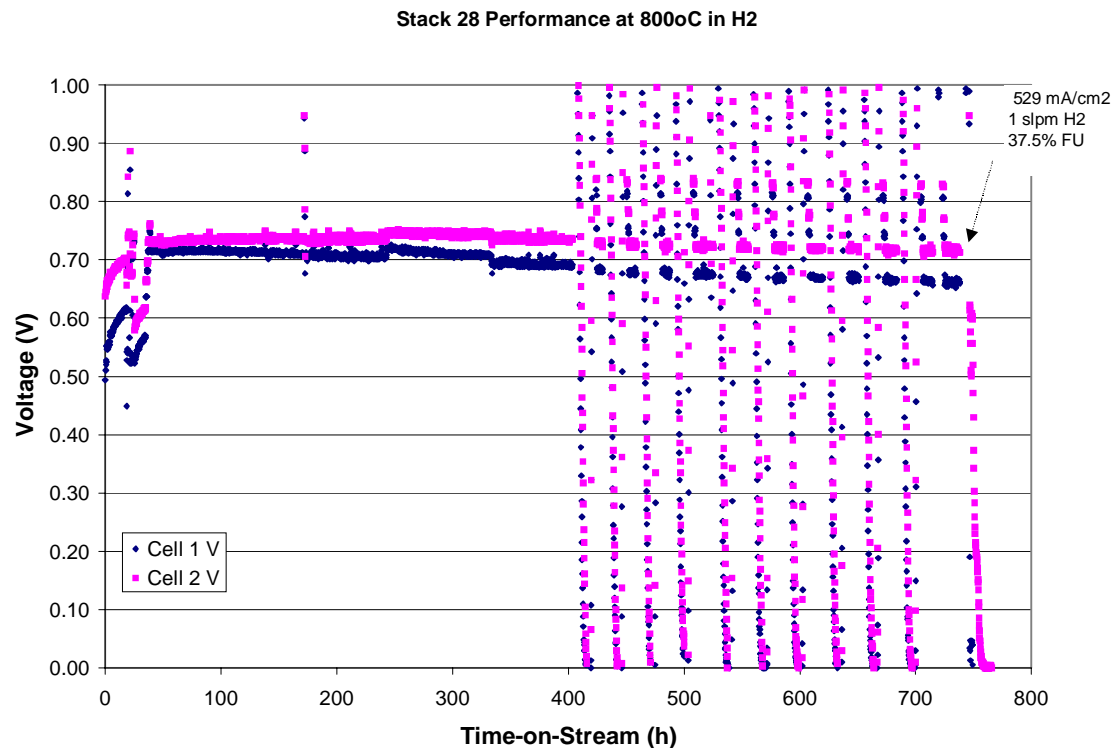
SOFC Stack Performance



- 10 cm x 10 cm footprint
- 800°C operation in hydrogen and air at ambient pressure
- Power:
 - 1.1 kW at 0.7 V / cell
 - 1.4 kW at peak power
- Power density:
 - 0.42 W/cm² at 0.7 V/cell
 - 0.6 W / cm² at peak power
 - 0.7 kW / kg, 0.7 kW / L at peak power
 - 0.53 kW / kg, 0.53 kW / L at 0.7 V/cell

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Stack Thermal Cycling

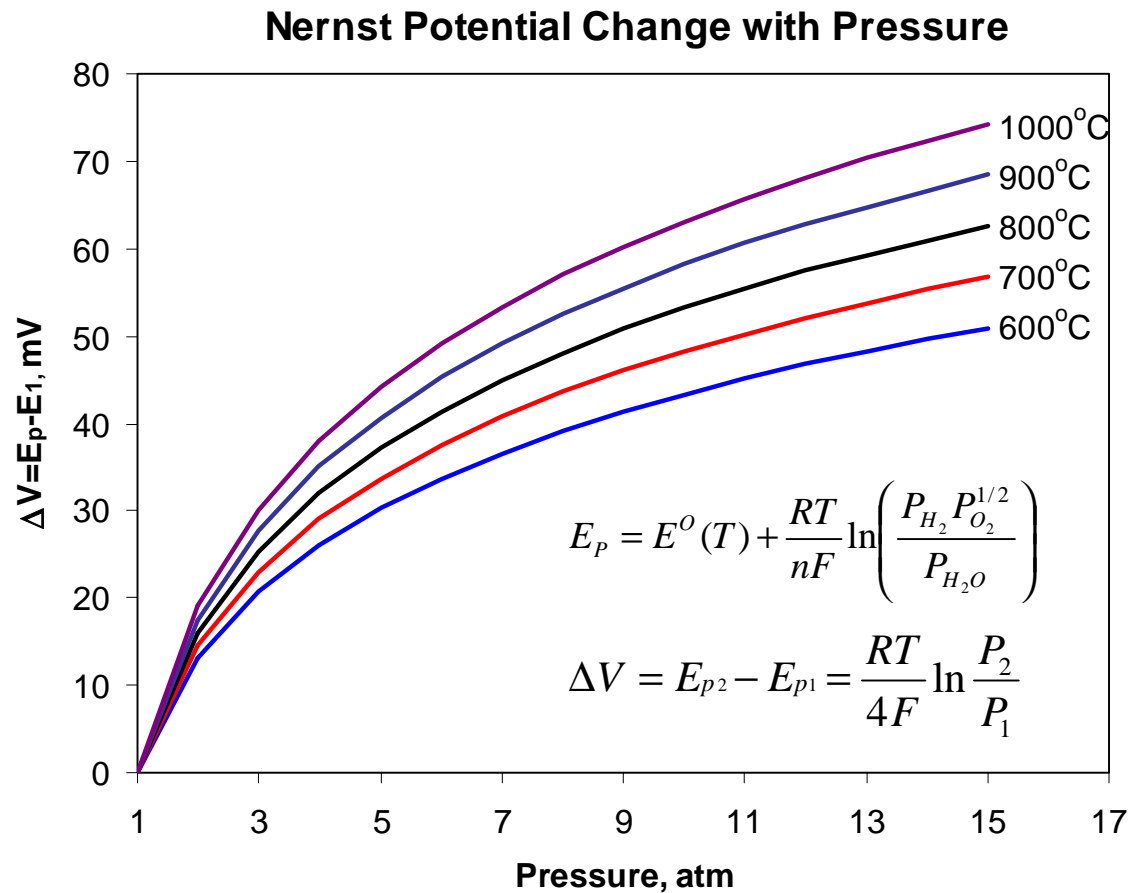


- Multiple thermal cycles without significant performance degradation
- Minimal change in open circuit voltage and voltage under load between cycles

SOFC Performance Enhancement with Pressure

- Cell performance is enhanced with pressurized operation thermodynamically and kinetically
 - Increase in Nernst potential
 - Decrease in activation polarization
 - ◆ Exchange current density
 - Decrease in concentration polarization
 - ◆ Limiting current density

Nernst Potential Increases with Pressure

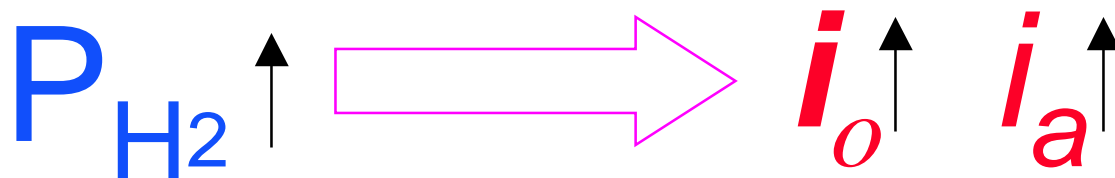


Electrode Kinetics Enhanced with Pressure

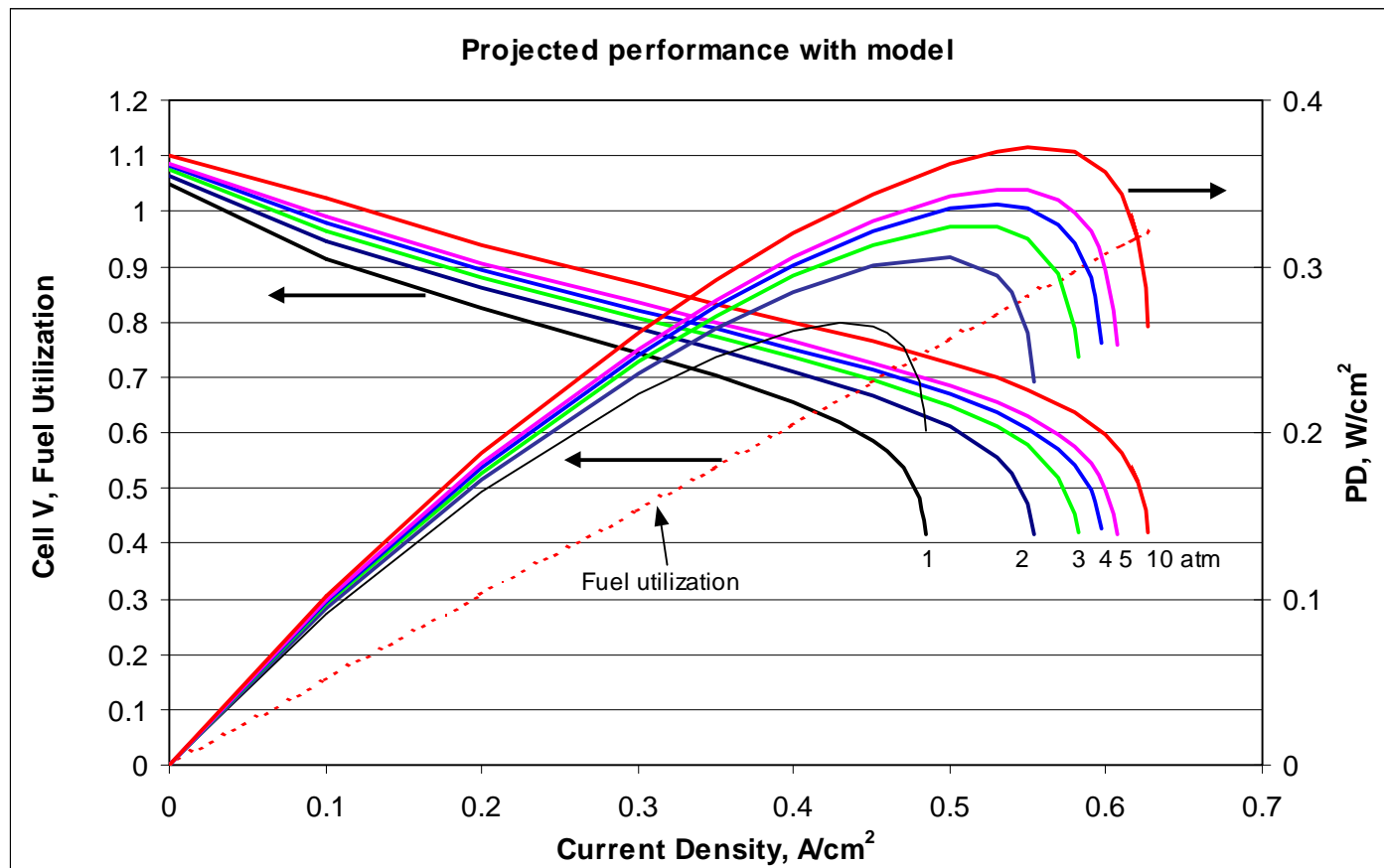
Pressure will benefit electrode kinetics through increase in both exchange current density and limiting current density

Exchange Current Density i_o

Electrode Limiting Current Density i_a

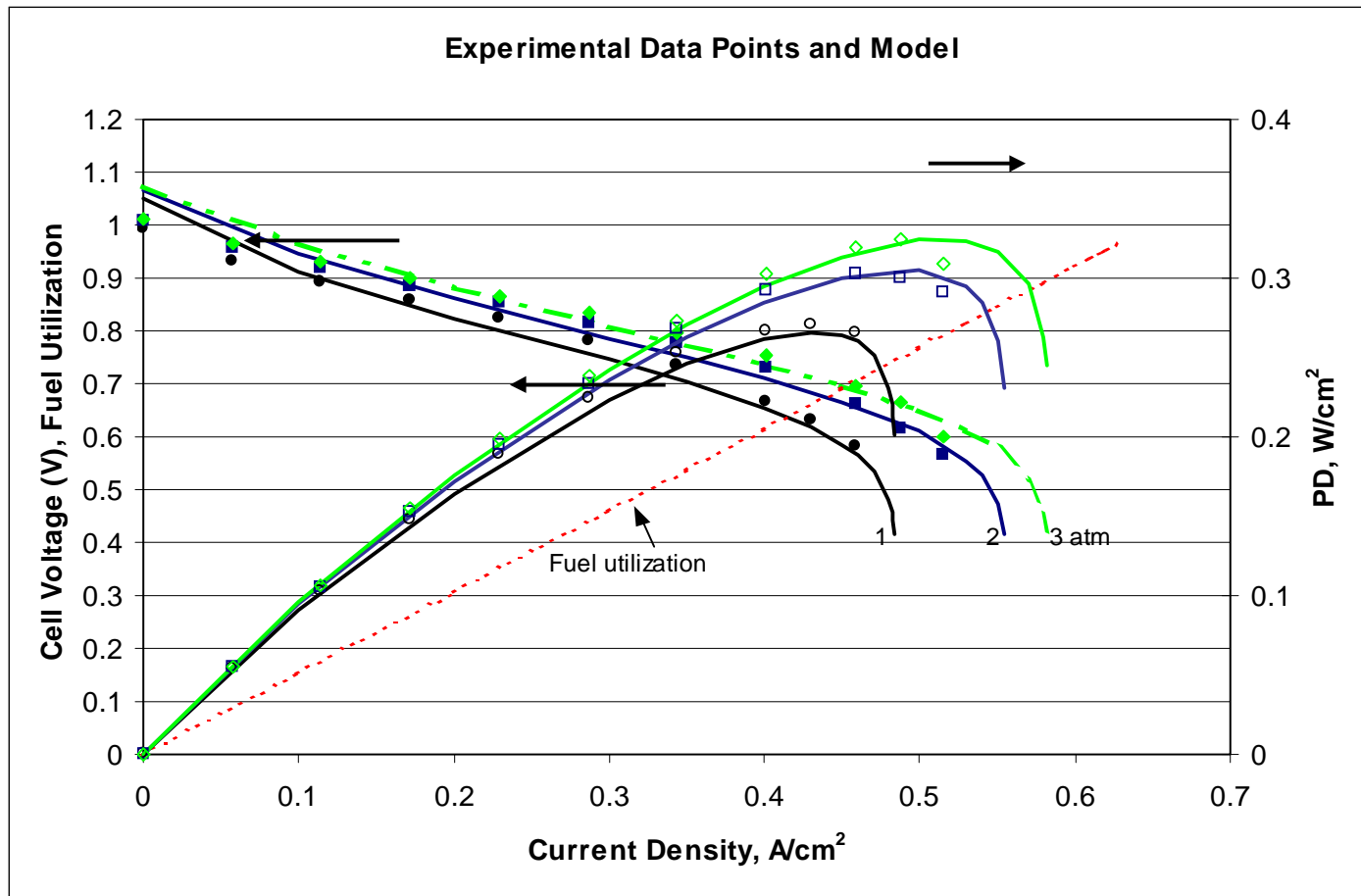


SOFC Performance Projection



- Significant performance enhancement observed from 1 to 3 atm
- Moderate performance improvement expected from 4 to 10 atm

Pressurized SOFC Performance



Concluding Remarks

- **SOFC-turbine hybrids have potential for high efficiencies over a broad range of system sizes**
- **Preliminary system concepts have been evaluated**
- **Pressurized operation for planar SOFCs has been demonstrated**